Development of a Math-Learning App for Students with Visual Impairments

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Abstract

The project was conducted to make an online tutoring program for math word problem solving accessible to students with visual impairments (VI). An online survey of teachers of students with VI (TVIs) guided the decision to provide the math content in the form of an iPad app, accompanied by print and braille materials. The app includes audio descriptions of images that illustrate the math problems, an integrated Scratch Pad, options to adjust color and contrast, hints, and videos showing how to solve sample problems. In order to provide access to those needing screen reading technology or screen enlargement, the app utilizes the Apple built-in accessibility features of VoiceOver and Zoom. A study with 19 TVIs and 29 students with VI was conducted to obtain feedback about the app and materials. Comments were generally positive, but both students and teachers reported that the quality of the hints varied and that the videos were not very helpful. Thus, the hints were revised, and narrated videos showing step-by-step solutions were added to each problem. A single subject study is in progress to compare students' performance when using the app and materials with the traditional way they access math materials (print, braille).

Keywords

Visual impairment, math learning, iPad app, technology

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Introduction

Educators, researchers, and practitioners have noted that math learning is often especially difficult for students with visual impairments (VI), and that this may contribute to their low numbers in math-intensive college majors and professions (Freeland, Emerson, Curtis, and Fogarty; Goertz, van Lierop, Houkes, and Nijhuis; McDonnall, Geison, and Cavenaugh). In particular, algebra is a critical "gatekeeper" course. Students who do not pass algebra are not likely to pursue science or engineering. Often, the problem is that students lack proficiency in key algebra-readiness skills such as division, fractions, decimals, and unit conversion. To address the need to help students with VI build their algebra-readiness skills, the present project was designed to adapt an existing online tutoring program for use in authentic educational settings by students with VI, and their teachers of students with visual impairments (TVIs).

Discussion

The AnimalWatch program

The original online tutoring program ("AnimalWatch") was developed with support from the U.S. Department of Education (Beal, Arroyo, Cohen, and Woolf). The program emphasizes word problem solving, which is generally considered a key component of mathematics proficiency (Koedinger and Nathan). An efficacy study involving a randomized control trial (RCT) design indicated that classroom use of the AnimalWatch software in California middle schools was associated with improved scores on the state end-of-year math achievement test (Schneider, Beal, Hauk, D'Silva, Li, and Allen). However, the web-based program was not fully accessible for students with visual impairments. Thus, the project goal was to make the AnimalWatch program accessible.

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Selection of iPads as the delivery platform

The initial project challenge was to identify the best platform to meet the needs of students with a range of visual abilities (low vision to educational blindness) and literacy media used to access information (print, braille, audio) (Zhou, Parker, Smith, and Griffin-Shirley; Zimmerman, Zebehazy, and Moon). The Project Team developed an online survey that was open in Spring 2012 to TVIs. Results indicated that TVIs (N = 88, from 27 states) believed that the iPad platform, which includes Apple-proprietary accessibility features such as VoiceOver, an integrated speech option, held the most potential for effective delivery of math instruction to their students.

Features of the app

During the 2012-2013 school year, we developed a prototype iPad app ("AnimalWatch Vi") along with accompanying materials, and obtained feedback from students with VI and TVIs.

Math content. In its final form, the app includes 24 units covering math topics such as fractions, decimals, unit conversion, solving one-variable equations, basic statistics, and basic geometry. Each unit includes six word problems, each with two hints that are available to the student after he or she enters an incorrect answer, and a short video showing the problem solution that becomes available if the student cannot solve the problem. Two problems in each unit include graphical information such as maps, tables, bar graphs, and diagrams. Students with VI often lack opportunities to work with graphical information, yet this type of information is often emphasized on math achievement tests.

Accessibility features

All text on the screen can be accessed in audio form either via VoiceOver or by a two-finger single tap, which activates the app's internal speech that sounds like VoiceOver to the user.

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Areas of the screen can be enlarged using the Apple accessibility feature Zoom. A Settings page within the app allows students to select a font color and background combination to maximize usable vision, to fade or eliminate decorative artwork, and to adjust the audio speed. An Answer Pad allows the student to enter answers and receive immediate feedback. The Answer Pad is linked to a moveable Scratch Pad available for those with usable vision to do their computation. Features of the Scratch Pad allow the student to adjust the line thickness of the pen, undo the last pen stroke, or erase the page.

Accompanying materials

Hard copies of the word problems are provided in braille. The graphics (maps, bar graphs, diagrams) in each unit are provided in print or braille based on the student's literacy medium. The graphics are also visible on the screen and audio-described. All materials were reviewed and approved by members of the project team, which included experts in math education for students with VI, braille transcriptionists, TVIs, and a high school student who is a braille reader.

Implementation

The app is built in the iOS programming language. Content (word problems, audio files, images, videos) is downloaded to the student's device. The app is also connected to a project database that records user actions (e.g., log files that include incorrect answers, requests to view hints or videos) to support the research. The log files are uploaded automatically to the database whenever the device detects that it has Internet access. The database also allows the research team to manage the content by logging in and updating problems, videos, images and other features, and to assign specific units to particular students.

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Feasibility study

In Spring 2014, we conducted a study to determine if students and TVIs would be able to use the app and materials in a classroom setting. TVIs (N = 19) participated in a two-hour training and then introduced the app and materials to their students (N = 29), starting with an introductory unit designed to provide an overview of the features of the app and an opportunity for students to customize the app's settings to maximize their access. Students completed six units involving appropriate math content that had been selected by their TVIs. Both groups of participants provided feedback via individual telephone interviews.

The response from users was generally positive. One TVI of a 6th grader shared, "I love the whole thing. I wish it covered kindergarten through 8th grade or high school… There is nothing out there like it. I want more!" Participants also provided feedback about specific features that was used to guide a final round of revision. For example, students liked the word problem hints but reported that the quality of the hints was inconsistent. Also, the help videos were too long and generic (i.e., not specific to the problem that the student was trying to solve) to be useful. One teacher commented, "It would be more helpful to see steps on how to get the answer so then on the next problem she might be able to do it." These suggestions were addressed by re-writing all hints to ensure consistency of approach (e.g., Hint 1 provides a guide about the operation, and Hint 2 provides more specific guidelines involving the numbers in the problem). In addition, each problem now has a brief narrated video showing its step-by-step solution.

Discussion

The study results indicated that we were reasonably successful in adapting an existing web-based resource for use by students with visual impairments through implementation in the form of an iPad app. Interestingly, however, the app alone was not viewed as sufficient. Both

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students and TVIs indicated that the hard-copy materials were a valuable complement to the app. Students with low vision typically accessed the maps, tables, bar graphs, and diagrams on paper rather than on the small iPad screen. Students who were braille readers noted that they would refer to the braille book as a backup when solving more challenging word problems. Thus, technology alone is not likely to be a complete solution to how to access content such as mathematics, which is heavily visually and conceptually based.

Several challenges remain to be addressed: First, the display of some mathematical equations in Nemeth code is not correct when produced via a refreshable braille display. This is complicated by the fact that the United States is transitioning to the Unified English Braille (UEB) code. Decisions will need to be made about whether mathematical content is presented in UEB or Nemeth code since that code is being retained in the United States. Second, the audio files generated from the database text files were sometimes inconsistent (e.g., a decimal point might be read as "dot" or "point" in different contexts). Pronunciation was also sometimes unclear or incorrect (e.g., "live" was sometimes pronounced as "liv").

An evaluation study to assess the promise of the instructional package is being conducted in the 2014-2015 school year to compare the app and its materials to the traditional way in which the student accesses math content (e.g., print, braille). TVIs in the study will collect data as the student works using an iPhone/iPad app built for the project. TVIs will record any materials used by the student, the amount of help provided, and how motivated and engaged the student appeared to be, and their data will be uploaded to the database for integration into the student log files. One possibility is that students will be more successful with, able to work more independently, and show a preference for the app, which includes hints and solution videos, whereas static print or

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braille versions do not. Alternatively, students may prefer to use the resources that are more familiar to them.

Conclusion

The project goal was to make the word problems from the AnimalWatch online math tutoring program accessible to students with visual impairments. The design process involved soliciting input from teachers to identify the most appropriate platform and features. The initial prototype was then tested in the field with students and TVIs, whose feedback was used to drive a second cycle of development to refine the features. In general, users reported a positive impression of the app prototype and its accompanying materials. Students indicated that the app was interesting, its layout was intuitive, and that they enjoyed learning about the animals described in the word problems. The TVIs reported that students were able to navigate the app independently, and their knowledge of math content improved. These positive reports need to be confirmed with a study in which measures of student learning are included. In general, the results point to the potential of technology to support access to instruction for students with visual impairments.

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